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ABSTRACT

This document is designed primarily to help teachers in elementary and middle schools to teach basic skills in mathematics, the visual arts, and social interaction. The Introduction contains sections titled: (1) How and Where to Begin; (2) Orientation Exercises; (3) Discovering the Environment; (4) Toothpicks and Gumdrops; (5) A Process for the Product; and (6) Tips from the Architects. The next major section, Models, makes up the bulk of the material. Four individual activities that have been carried out successfully with varying ages and numbers of pupils are detailed. Each model discussion concludes with a review of related projects that have also been completed. The document concludes with a glossary of terms and a listing of suggested sources and resources. The glossary examines in separate sections terms relating to the environment, to horticulture, and to land planning and design. The resource list contains sections on books, periodicals, sources, and contacts. (MP)

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MARA

Mathematics/Architecture Related Activities

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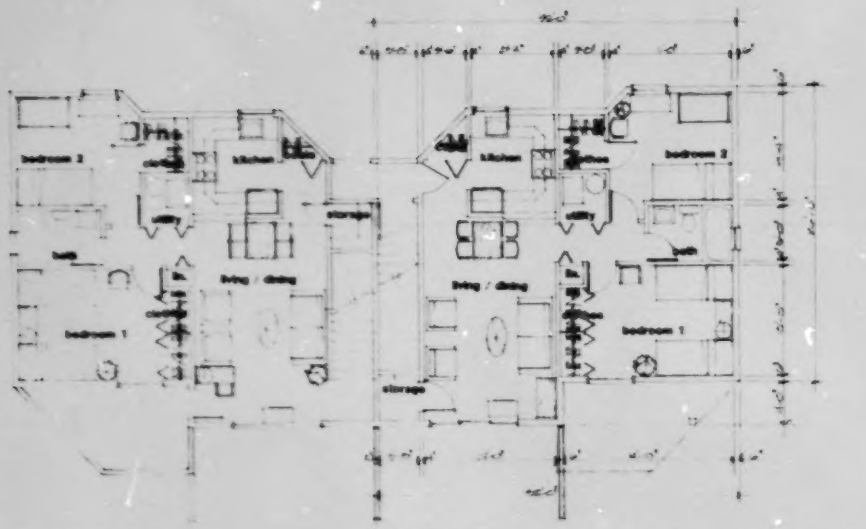
FOREWORD

Since architecture is "the art or practice of designing and building structures . . . in accordance with principles determined by esthetic and practical or material considerations," it is hoped that this handbook of mathematics/architecture related activities will help to build significant bridges between art and mathematics via social interaction, for the improvement of pupil performance in all three areas. Anticipated outcomes include heightened awareness of surroundings and relationships; increased sensitivity to materials and their effects; development of planning skills, problem-solving techniques, and capabilities in visual design and execution, computation, and group participation; and, perhaps most important, application of these skills and knowledges to human service.

Designed to help classroom teachers in elementary and middle school (grades K-8) to teach basic skills in mathematics, the visual arts, and social interaction, the publication supports the New York State Plan for Basic Skills and was made possible in part by funds from the ESEA, Title II Basic Skills Improvement Program. The activities described within it were drawn from Architects-in-the-Schools component projects, primarily in White Plains, New York. The manuscript was written by Trish Jamison, education writer and representative of the New York State Congress of Parents and Teachers on the Commissioner's Advisory Council on Integrating Arts into Education, after frequent site visits and personal interviews with architects and members of the White Plains and New York City school systems. Of particular help were architects Allan Anderson, Frank Giuliano, Matthew Kroin, Kenneth Narva, Frank Santillo, Sharon Suttin, Leonard Weinberg, and Howard Wolff, and educators Paul Greene, Joan Sanger, Herbert Shapiro, William Smythe, Ronald Topping, and George Yanchik. Additional assistance was provided by Barbara J. Rodriguez, executive director of the New York State Association of Architects, Inc., the State organization of the American Institute of Architects. Toni Meyer, Robert L. Reals, and Rita A. Sator, associates in mathematics education, visual arts and humanities education, and curriculum development, coordinated the project, edited and, in some cases, revised the manuscript, secured the photographs, and prepared the publication for press. Kim Thomas provided the technical assistance on layout, and Pat Mulligan and Bruce Stewart developed and executed the publication's layout and design.



second floor plan

first floor plan

2 BEDROOM WALK-UP UNIT

front elevation

4 TWO BEDROOM WALK-UP UNITS

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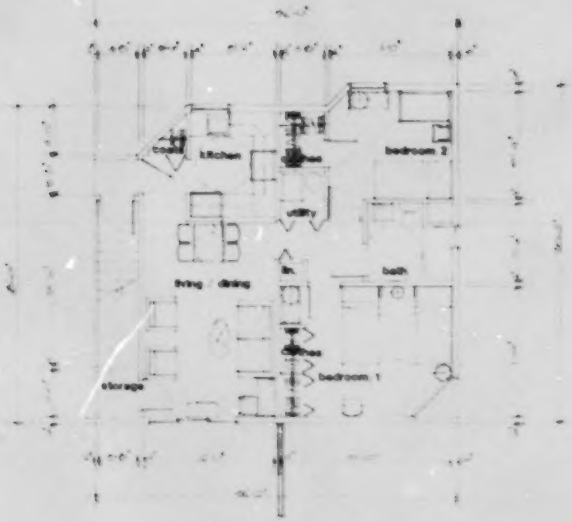
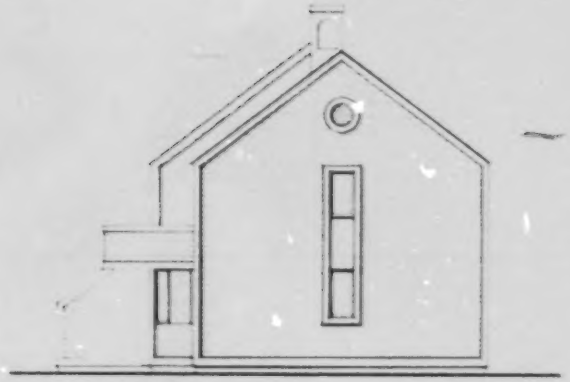


handicap unit



side elevation

Architecture Is Used To Build Skills

The arts play a basic role in the learning process by fostering the development of internal imagery. Parents, classroom teachers, art specialists, and administrators, working in concert, can give a generation of children many and varied primary experiences, the materials and tools with which to work their sensations through to imagery by painting, drawing, singing, building, acting, dancing - those activities they are drawn intuitively to try anyway. We have no way of anticipating the problems of the future and cannot teach children the facts with which to cope. Instead of teaching them what to think we must teach them how to think if we are to have an inventive, creative, and meaningful society. *

This handbook is intended to do just that - to help teachers in grades K-8 to help their students to:

- Develop a life-long love for learning;
- Master basic skills in creative as well as rational thinking, problem solving, measurement, computation, spatial relations, ecology, visual design, construction, communication, and social interaction;
- Appreciate their environment, and understand both the positive and the negative effects of human impact upon it; and
- Experience a justifiable pride in performance

through the mathematics/architecture connection.

"Architecture is the art of organizing space" (Auguste Perret). It is an ordered, but flexible art which combines elements of human need, language, mathematics, and both the social and the traditional sciences with esthetic skills. It deals with structuring the environment, but is not restricted to buildings. Like mathematics, it requires the ability to define and solve problems. Observation, discovery, intuition, experience, and accuracy all play a part in the process as it moves from stage to stage: from analysis to design to construction to evaluation. Concepts must be tied to reality but, within these parameters, there is ample freedom to experiment, and the best products are as esthetically satisfying as they are functional and well made.

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*INTEGRATION OF ARTS INTO EDUCATION, prepared by constituent associations forming the New York State Council of Educational Associations, 1980.

The mathematics/architecture connection provides a powerful incentive for learning because it:

- Deals with the students' environment and is therefore relevant;
- Combines skills and knowledges from several subject areas in meaningful ways;
- Encourages students to work together, each making a special contribution to a common end; and
- Results in a visible and tangible product of which the creators, individually and as a team, can be justly proud.

The connection is remarkably adaptable and has been used successfully with all kinds of students - average, gifted, and handicapped at various age and grade levels. School administrators have noted significant improvement in both teacher and student attendance and morale, and a decline in discipline problems and vandalism which they directly attribute to pride of ownership. Finally, mathematics/architecture related activities can have a positive effect on school/community relations. The students' enthusiasm, coupled with a spirit of cooperation and demonstrable improvement in academic achievement, engenders widespread community support for the school and its policies, activities, and personnel.

The activities described on the following pages have been chosen to illustrate different ways to make the mathematics/architecture connection by using features of the disciplines which parallel and enhance one another. Since the activities are merely samples of what is being done in a limited number of schools in New York State, they should be considered more as stimuli than as resources. The approach is experiential.

HOW AND WHERE TO BEGIN

It is advisable to begin a mathematics/architecture project with the assistance of a local architect. Professional architects bring a special kind of validity into the classroom. Decisions with regard to the content of the project should be based on local needs and resources. In some of the projects described in this publication, students identified specific aspects of their school and its environment that they felt could be improved.

Following the selection of a project, students should develop an accurate understanding of what architects do and the kinds of tools they use, as well as an awareness of the architectural process. Architects are planners and developers. While they may be versed in the use of hammers, saws, and shovels, the real tools of the trade are T-squares, triangles, compasses, and scales (rulers). The designs developed by these professionals must reflect the goals and requirements of their clients. These needs affect programming, research, schematic and preliminary designs, working drawings, construction management, and final approval. This is as true for private dwellings as it is for public projects like shopping malls, offices, parks, playgrounds, factories, and air terminals. A brief illustrated review of the history of architecture from Egyptian pyramids to modern structures reinforces the concept of meeting human needs in a variety of imaginative and practical ways. Architects are also concerned with making an ally of nature by working with the environment rather than against it.

The concept of structure is easily introduced to young children by using blocks, pieces of double corrugated cardboard, and even the children themselves to demonstrate the principles of columns and beams. (A child stretched across two chairs can become a beam.) Structure is used to help define a place. Places and spaces have dimensions of height, width, depth, texture, light, color, and material. Each dimension affects the mood of the place or space. This aspect of place is often illustrated by a discussion of the classroom and how it would feel if the ceiling were a foot lower, the walls painted a different color, or whatever. Some understanding of client needs can be promoted at the same time. Students should also be encouraged to discover geometric shapes inherent in buildings and plans, the importance of making accurate measurements, and the value of estimation. The earlier in the project the connection between mathematics and architecture is made, the stronger the link will be.

ORIENTATION EXERCISES

Discovering the Environment

The brief warmup activities that follow are designed to develop in students an awareness of both the natural and the built environment by increasing their ability to observe details, similarities, differences, and relationships in the world about them. All activities, whether completed at home or in school, should be discussed in class. Ask the students to do one or more of the following:

- Sit in your room at home and take a good look at it. Then make a picture of everything that is in it.
- Draw a front elevation of your house or apartment building and point out the one thing that makes it unique. (A front elevation is a picture of the front of the building.)
- Plot the fastest way home from school and make a map of it.
- List all of the different kinds of buildings between your home and school. Note how many stories each has and what building materials were used.
- List all of the materials (e.g., wood, plaster, plastic) used in your classroom.
- Measure the classroom and make a scale plan of it. Then, using dotted lines, map the traffic pattern into, within, and out of the room. Jot down such observations as how the room is heated, cooled, ventilated, and lighted; whether people can breathe, see, and hear well in it; what is good about it; and what is bad about it. How might the room be changed?
- What would an ideal classroom look like? Make a plan, a picture, a list of details, or a narrative description of it.

The activities suggested above can be modified to stress mathematical concepts being studied at the time.

Toothpicks and Gumdrops

Common round toothpicks or matchsticks and small gumdrops or stale miniature marshmallows (gumdrops are preferable in very warm weather) can be useful in helping students to discover some of the basic architectural and geometric principles.

- Distribute handfuls of toothpicks and gumdrops to the class and have each student construct a simple two-dimensional form (triangle, rectangle, pentagon, or whatever), using whole or broken toothpicks for rods and gumdrops for connectors. Allow 2 or 3 minutes.

- Ask the students to create new shapes by pushing and pulling the sides and corners of their constructions without lifting the gumdrops or marshmallows from the surface of the desk or table. If necessary, demonstrate with an overhead projector. They should begin to see that every shape except the triangle can be changed (e.g., rectangles become parallelograms), and thus discover the theory of triangular rigidity.

- Put one of the constructions on the overhead projector or in a place where all members of the class can see it. Ask the students to describe what they could do to make the form rigid enough to keep its shape even when pressure is applied to the sides and corners. Let them experiment with the answers. Repeat the activity with another construction. After several of these experiments, the students should be able to generalize that any structure will maintain its shape if it is composed of triangles.

- Selecting one of the constructions, have the students explore several ways of dividing it into triangles and then determine which of these might be the most economical, esthetic, or practical. Ask them to identify examples of the principle of triangular rigidity in pictures and in neighborhood structures like railroad overpasses and houses under construction.

- Give the class free rein to build three-dimensional forms and then subject several of the constructions to stresses similar to those used earlier with two-dimensional forms.

- Divide the class into teams and ask each team to build a toothpick-and-gumdrop structure that will support three given textbooks. After several attempts, the students should discover that toothpick structures can support up to 10 kg. Analyze with the students those forms which do not support the required weight in comparison with those that do support it. Encourage discussion and conjecture. How could the unsuccessful structures be modified to hold the weight? The activity might be extended by the consideration of such questions as the following:

  - How much rigidity is beneficial for a bridge? for a tall building? Why?
  - Does a beam have to be thick to be strong? Why or why not?
  - How important is shape to strength? Which shape is the strongest? Under which circumstances?
  - What makes a building stand up? What keeps a bridge from collapsing?

A PROCESS FOR THE PRODUCT

An environmental structure designed to meet a client's needs or to solve an architectural problem is the result of a clearly defined process. This process requires the use of problem-solving, planning, executing, and evaluating skills at every stage of development of the structure.

1 ANALYSIS

What To Do	What To Think About
• Take inventory . Use all the senses . Measure	• What are the characteristics of the area to be changed? . What do I see? . What do I hear? . How long, wide, and tall is the space?
• Make a map or a chart	• What does the area look like now?
• Analyze the data	• How will the characteristics of the area affect the project? • Which of these characteristics is/are most important? • Can any of them be changed or eliminated?
• Brainstorm	• Given the situation found above, how can the need be met or the problem solved?
• Research	• What have other people done to meet a need or solve a problem like this?
• Choose a solution	• Which idea will work best?
• Develop design criteria	• What must the solution do? • How will it relate to its surroundings? • What is the most it can cost? • If there is one, what would the client like?

2 DESIGN

What To Do	What To Think About
• Make freehand sketches	• How would it look if . . .? (Try different ideas - don't get stuck on one.)
• Make sketch models of paper or clay	• Which seems to be the best idea? (Experiment with combinations of ideas.)
• Draw the best idea to scale on graph paper . A plan (top view) . Elevations (side views)	• Why is this the best solution? • How big (length, width, height) is the proposed structure or change?
• Show how to make it	• What will it be made of?
• Make a materials list	• What will be needed? (Remember to include tools.)
• Check the design against the criteria	• Will the solution do what it is supposed to do? • Will it be safe? • Will it be attractive? • Is it affordable? • Will the client like it?
• Discuss the design with others and make any needed changes	• How can it be improved?

At this stage, the architect becomes consultant and monitor to the builders who translate the design into reality. Since corrections are usually needed with even the best designs and building craftsmanship, the architect and the builders must work together as partners in the project.

3 CONSTRUCTION

What To Do	What To Think About
• Make a shopping list	• Which of the items on the materials list do we already have? • Which can we borrow? • Which must we buy?
• Get estimates from suppliers	• Where can we get the best deal?
• Make a budget	• How much will the project cost? • Is the cost within our limits? • If not, what can we do about it?
• Get the materials	• When and where should the materials be delivered? • How can we get those that will not be delivered?
• Develop a work schedule	• Who will do what, when, and where?
• Build or remodel	• Where do we start? • What comes next? • Are we on schedule?

4 EVALUATION

What To Do	What To Think About
• Examine the product	• Is it finished? • Does it meet the criteria? . Does it do what it is supposed to do? . Is it safe? . Is it attractive? . Was it within our budget?
• Present it to the client, if there is one	• Is the client pleased?
• Open it for use	• How do others respond to it?
• Take inventory	• How is it being used? • What is good about it? • What would make it better? • What advice could be given to someone with the same need or problem?

TIPS FROM THE ARCHITECTS

All of the architects interviewed for MARA have had classroom experience as "architects-in-the-schools." Although they did some direct teaching, their major functions were to provide technical assistance and to lend importance, meaning, and authenticity to the projects. The following observations are derived from their experiences with students and teachers:

- The commitment of the classroom teacher is crucial.
- The success of major projects which are completed over time and result in either permanent or temporary changes to the built environment depends to a great extent on the success of team instruction. Well integrated, smoothly operating projects result when each member of the instructional team (visual arts specialist, classroom teacher, architect, and others) understands clearly the separate mathematics, art, architectural, and behavioral goals of each activity. A series of orientations over two or three months is preferable to a single 3-hour session.
- It is easier and often more satisfying to the students if the project can be completed on or near the school premises.
- All functions, especially the choice of project, should include the greatest amount of student participation possible.
- The younger the students, the more immediate should be the results.
- Early and accurate understanding of difficult concepts is promoted by the consistent use of correct terminology at all times, regardless of the age or developmental level of the students.
- Flexibility is part of each phase of the process. Adjustments are normal and are an integral part of growth. Expect the unexpected!
- Teachers should be flexible about time given to practice as well as about time given for thinking and experimenting.
- Free movement, questions, and adequate discussion of all related parts of any activity should be encouraged.
- During the construction stage, the simpler the tools and materials the better. Even so, direct instruction in the proper use of tools and materials and specific safety precautions are imperative!
- With guidance and practice, students can begin to <u>see</u> when they look and <u>hear</u> when they listen.

Small Architects, Big Plans

MODEL I: CLASSROOM REDESIGN

This model was used with a single fifth-grade class. The architect met with the students for about 90 minutes each week for seven weeks. Because the classroom teacher was fully in tune with the project, the architect became a genuine resource who brought a special focus to the classroom activities which occurred during the week between visits.

This model is particularly flexible. Details may be modified to accommodate almost any time frame and budget as well as almost any student age group. Wise planners will be sure to allow time for the students to enjoy the fruits of their labors by scheduling completion well before the last week of school.

ART LEARNINGS

Scale

Proportion

Elements of Design
- color
- form
- light
- line
- shape
- space
- texture

Drawing

Orientation

During the architect's first visit with the teacher and the students, the different phases of the project (analysis, design, construction, and evaluation) were reviewed and noted on a large drawing pad with magic markers. In the discussion which followed, the group identified a problem and defined a goal: redesigning the classroom to include one area for day-to-day teaching and another for an activity center.

Analysis

Before the architect's next visit, the students measured and inventoried every element of the existing classroom space. During the second visit, they drew a scale floor plan of the classroom on a large piece of brown paper (1 m x 2 m), using metric rules and tapes. They cut out scale shapes of each piece of furniture and placed these on the floor plan to see how the classroom looked in its present configuration. Then they discussed the good and bad aspects of the present layout, including such features as circulation, entry, public versus private space, outdoor light, fixed perimeter, service cores, and storage.

Design

The 18-member class was divided into teams of three. Each team was given one week to develop a new layout which:

MATH LEARNINGS

Linear Measure

Ratio

Proportion

Perimeter

Area

ART LEARNINGS

- Included all of the elements of the existing classroom,
- Changed neither the structure nor the location of permanent fixed units,
- Devoted no more than 20 percent of the classroom space to the activity center, and
- Allowed the activity center to coexist successfully with the day-to-day teaching area.

Cooperative Designing

Two sessions were devoted to a critique of the six schemes. The students sat in a semicircle with an enlarged outline of the existing classroom and all fixed elements in the middle. Each team presented its solution to the problem, using the inventory of movable classroom elements which they had measured and cut to scale in the previous session. As each solution was presented, it was photographed with an instant camera and critiqued. All comments were recorded. Then a new design was formed from the best features of the individual layouts. The following checklist was used in the process.

MATH LEARNINGS

Percent

Permutations

Combinations

FEATURE	Yes	Somewhat	No
ENTRY • Is it clear? • Is there enough room? • Can I tell where things are? • Can I go to each task area easily?			
DESK LAYOUT • Is there enough room to work? • Is there enough room for instruction? • Is there good circulation around the desks? • Do the desks take up too much space in the classroom?			
RESOURCE INFORMATION AND EQUIPMENT • Are items near required utilities? • Are they accessible for teaching? • Is there enough room for them?			
ACTIVITY CENTER • Is it well defined as a separate area? • Is circulation to it and around it clear? • Is it 20% of the classroom space?			
GENERAL LAYOUT • Does the classroom layout make the best use of the fixed elements in the classroom? windows? closets? bulletin boards? utilities? skylights?			

ART LEARNINGS

Interior Design

Construction

After the students had agreed upon a design, the teaching area within the actual classroom was rearranged in accordance with it. No additional furniture or material was required.

Then a detailed discussion of the activity center was held. Since some new materials were considered necessary for this area, a budget, a shopping list, a time schedule, and team construction assignments were made. When complete, the activity center included a place for a colonial crafts display, a weather station, and a place to play educational games and view filmstrips.

Evaluation

The finished product was evaluated in terms of the checklist developed in the design stage and every question was answered by a "Yes," but the greatest proof of its success lay in the junior architects' use of their redesigned classroom and the obvious pride they felt in their achievement.

MATH LEARNINGS

MATH-RELATED ACTIVITIES

1. Using metric measure
2. Applying the principle of triangular rigidity to a free-hanging shelf
3. Developing two- and three-dimensional designs to scale
4. Determining percentages of area
5. Measuring space requirements in motion
6. Measuring light
7. Developing budgets based on estimates of time and costs

SUGGESTION: Unless the furniture is nailed down, move it freely. Some people have difficulty visualizing how a plan on paper would look when implemented.

RELATED PROJECTS

Lofts and Other Living Levels

Among the many variations and extensions of Model I: Classroom Redesign is the creation of a loft activity center, enclosed reading corner, and central study module in a school library and a student lounge composed of movable plywood units in an unused classroom of a soon-to-be-vacated school building. The architects were sixth-graders working with a professional architect. Two of the activities are described below.

The library loft was constructed after a schoolwide competition produced a design that incorporated a skylight which had been covered for a number of years. The structure was built as a freestanding unit prefabricated in panels by teams working in small groups for short periods of time and erected in two class periods spent on the site. The experience was not unlike an old-fashioned barn raising. Each member of the class participated in the construction stage even though power tools were used. (N.B. The building phase of any project should include direct instruction in the safe and proper handling of tools and equipment.) The students were motivated enough not to have any problems with the strict rules governing the use of power tools, and everyone discovered that it was quite possible to have a good time working hard and not "fooling around." A coat of yellow paint warmed the wood, finished the project, and cheered the library.

When the students were offered the use of a vacant classroom (their school was scheduled to close because of redistricting), they decided that what the school community needed most was a student lounge or special place for the pursuit of leisure activity. The sixth-grade class became the architect and the fourth-grade class, the client. The older students began by interviewing the younger ones to determine the "program" or outline of their client's wants and needs. In this case, the program included a quiet space, an art space, a place for audiovisual materials, and a disco.

The amount of available space and the fact that a move was imminent, which implied that whatever was constructed should be transferable, set the parameters for the design. The young architects formalized the program and then worked in groups to measure all existing elements and to make a cardboard model (scale 10 cm = 1 m) of the site. The professional architect discussed spatial relationships (height, depth, and levels) with the students as they explored together the possibilities of designing a split-level room. They also discussed the best kinds of materials to use for portable units that would tolerate the wear and tear fourth-graders could be expected to inflict. They decided to use standard-size (4' x 8') sheets of plywood to build hinged units that could be assembled, disassembled, transported, and reassembled fairly easily.

With these features in mind, the class designed several interiors and subjected them to a thorough critique, considering function, traffic patterns, and appearance, among other things. When a design was agreed upon, it was made to scale, and the finished model became the working plan or construction guide. The next step was to estimate, budget for, and order materials (two-by-four's, plywood, paint, glue, nails, and hand tools).

As the construction progressed, masking tape on the floor outlining the proposed units helped the students to visualize the environment and to find the problems for themselves. Adjustments were made as the work progressed, as they always are. The children learned that there is a place for imagination and innovation within the framework of discipline. Windows, for example, do not have to be square. On the other hand, there are times when precision counts. Measuring twice and cutting once is important - especially when $800 has been spent on materials!

The room was fascinating when finished, and bore some resemblance to a monster maze. It worked, and was a work of art. It also provided some positive experiences from negative space. Because the time schedule was unfortunately tight, the fourth-graders did not have too many chances to enjoy their room, but pieces of it still exist along with the ideas that were generated. It was a design which fostered sociability - one of the functions of architecture.

MATH-RELATED ACTIVITIES

1. Problem-solving activities related to best choices of geometric forms for various building purposes

2. Measuring as applied to scale, estimating materials, laying out patterns, and cutting wood

3. Budgeting activities as applied to costs, time, and labor (e.g., How much paint does it take to cover a particular surface?)

4. Developing statistics for use and traffic

MODEL II: FIRST IMPRESSIONS

This project was developed to give the entire population of a K-4 school, including special education classes, a sense of owning and belonging to their school. After a 3-hour orientation session with the school staff in November, a landscape architect worked with students and teachers from January to June, coming to classes an average of 8 hours a week. Each classroom session lasted from 3 to 4 hours. The younger children (grades K-2) were concerned with developing a bus arrival area just outside the school building, while the students in grades 3-4 redesigned a bus arrival hall just inside the building. Each group was able to watch the progress of the other and contribute ideas to their project. For both groups, the process included identifying and analyzing specific needs, drawing up plans, making scale models, choosing plants at a nursery, helping with installation, and forming teams to maintain the area. Some problems, like the planting of a tall tree with a substantial root ball by some very small people, required innovative solutions. (The children rolled the tree onto a mobile gym board and then moved it across planks to the planting hole.) The project succeeded in bringing a renewed sense of community to the school.

ART LEARNINGS

Scale

Proportion

Drawing

Orientation

During the architect's first visit, the entire student body was introduced to landscape architecture as a profession. The 16mm ASLA (American Society of Landscape Architects) movie A LEGACY FOR LIVING and slides relative to the profession were shown, and a discussion was held on the landscape architects' role in shaping our environment. The discussion promoted a basic understanding of the differences between architecture and landscape architecture. Small group discussions with question-and-answer periods were held in each class. The concept of scale was introduced. Two meanings of scale were clarified: proportion, as in human scale, and ratio, as in measured scale (5 cm = 1 m).

When the architect returned the next week, the students were ready to learn about scale, proportion, measurements, and principles of drawing. They learned the difference between a plan and an elevation and discussed models and blueprints. They measured an area and drew a base map to measured scale.

Analysis

After these orientation activities, the students were ready to begin the inventory phase of the redesign project.

MATH LEARNINGS

Scale

Proportion

Ratio

Measurement

ART LEARNINGS

Blueprint Drawing

Elements of Design
- color
- form
- light
- line
- shape
- space
- texture

The younger children were divided into teams of 5-6 students. Each team was assigned a space in the bus arrival area to survey and measure. As they began the site plan, the team members noted the vegetation and measured the grade with a transit. The older children met by separate classes in the bus arrival hall and drew measured plans of the space.

While the younger students performed soil tests on samples taken from the project site and studied vehicular and pedestrian circulation, the older ones analyzed the microclimate of the hall site, including sun angles, and discussed student circulation and use of the area. (N.B. This is a critical stage in the project: the importance of inventory and analysis in the design process must be made clear to all of the students. They should understand that a landscape architect must know every detail of the site to be designed.)

Design

At this point, both groups learned some of the fundamental concepts of esthetics, function, and design. They discussed criteria relating to the design process and looked at slides which illustrated how landscape architects had used specific design elements to solve problems which were similar to theirs. Then the students completed their own designs of the bus arrival area and hall, evaluated them in terms of the design criteria, and discussed the impact they might have on the environment.

Construction

Review sessions were held so that each class could look once more at the designs, choose one for each site, and begin model construction. Discussions centered around scale models and three-dimensional space.

By April the classes were ready to make fieldtrips to a local nursery and to study the marketing and growth of plants, since they needed to learn about the plant material

MATH LEARNINGS

Gradient

Angles

Statistics

ART LEARNINGS

used in their designs. (Plants and plant materials were included in the designs for both sites.) Plants were purchased during the fieldtrips and arranged according to the designs. The students learned how to plant and care for them, increasing their vocabularies along the way by using and understanding such terms as fertilizer, soil moisture, erosion, and herbicide.

Evaluation

The project was completed to the point of requiring on-site maintenance by mid May, leaving time for evaluation sessions and a grand opening before school closed in June.

The project increased the vocabulary of all the students (and the teachers) in the school by more than 50 words related to landscape architecture (see pages 35-37). These terms and new mathematical concepts were internalized because they were used over time and related to a large and very real project. Much of the measuring was done on the metric scale. Because they were integrated in a natural way, academic goals were easily met. There was also a measurable decline in vandalism to school property.

MATH LEARNINGS

MATH-RELATED ACTIVITIES

1. Measuring the site
    - Two-dimensional scale maps and plans
    - Three-dimensional plans and models (using a transit to determine grade)
    - Use of inventoried factors to influence adjustments
2. Plotting sun angles and other site factors, such as relating the depth of planting holes to the height of the items to be planted

3. Establishing causal relationships and probability rates between and among site factors, both natural and constructed

4. Financial budget estimating, adjusting, and setting

5. Time budgeting and cost estimates of work hours

6. Translating actual measurements to scale and back again with appropriate adjustments

RELATED PROJECTS

Withstanding the Elements

The several projects which are grouped in this model resulted in relatively permanent structures built to withstand the elements as well as the vagaries of human beings. All of the projects had to be timed so that the construction stage avoided the worst of the winter weather. Some flexibility had to be incorporated into the schedule to allow for rain. Tools and materials had to be stored in a dry, safe place. Allowances for these factors became part of the planning process.

Outside structures of any kind have the advantage of giving public visibility to the school's instructional program. In some neighborhoods, this positive image is important enough to become the main motivation for the entire project. Because they include active student involvement and often benefit from community volunteer help as well, the projects engender a sense of ownership that mere commercial construction - or repair - can never produce.

Successful outdoor projects require an extended and careful site-selection process. At the very least, students must thoroughly measure the areas under consideration and include the grade or pitch of the land in their calculations. Sometimes site-analysis maps are needed. Whatever form their observations take, however, the students will have noticed the orientation of the site, how the sun strikes it in winter and in summer, drainage patterns and problems, trees and shadows, prevailing winds, the microclimate, noise, views, access, and circulation. These features must be discussed and documented before a serious choice of location for the structure is made. Then, with care to fit the structure to its environment, the design process can begin. For outside structures, special attention must be paid to strength and durability.

Successful structures that have resulted from the architectural process include:

- A playground designed for older students by younger ones.
- A tot lot designed for younger students by older ones.

- A street museum telling the history of the neighborhood in pictures and words. The display is mounted under glass on a three-dimensional structure measuring roughly 4' x 4' x 10'.
- A "kiosk" for displaying school art projects. The display area consists of eight attached panels providing shallow glassed cases which allow for content changes.
- A playground structure in the shape of a pirate ship attached to a wharf.
- A playground structure featuring an airplane balance beam made from a donated telephone pole.
- A sculpture garden.
- An overnight shelter for campers.
- A Greek amphitheater, the rings of seats made of railroad ties.
- A street orchestra. This version consists of two freestanding structures of differing but compatible forms. Each structure has weather-resistant percussion instruments attached to it, and its design and construction encourage climbing. Each will accommodate several children at a time.
- Geodesic domes serving a variety of purposes.

Geodesic domes are popular with architects, teachers, and students for a number of very good reasons. The triangle which lends the dome its form is inherently stable, but it can be broken into components. Each line of a triangle adds a new dimension, from one to three. Uncovered, a geodesic dome built of firmly fixed strong material like bolted two-by-fours can function as a jungle gym. A clear glass-like covering can turn the dome into a greenhouse. A more opaque cover lends privacy to what could become an outdoor eating place, a rain shelter, or any number of other things. For indoor purposes, a relatively solid geodesic frame can be made of rolled newspapers and tape. One class built such a frame and threw a parachute over it, producing an instant playhouse. Newspapers, of course, are not strong enough to climb on.

When plantings become part of the design for an outdoor project, students have an opportunity to engage in another type of measuring exercise, that of measuring temperature. Air temperatures and sun exposures play a vital part in the life and health of plants. When a mulch is added to control weed growth, students sometimes do not realize that they have quite literally put a blanket on the earth and changed the temperature of the soil. One class, having planted daffodil bulbs in late October, was observed digging one of the bulbs up on a warm day in May. The students wanted to know why their bulbs had not blossomed in April. The bulb which they extracted had a 6-inch growth of yellow leaves, indicating that it thought it must be March. The students found, by taking the soil temperature, that the bulb was in soil 20° colder than the air. The mulch had contributed to the natural insulation of the soil, and the bulbs were too cold to bloom. Although this particular class was quite young (second-graders), involvement in a problem which touched each member paved the way for a very sophisticated exercise in mathematical problem solving.

All of the outdoor structures described or alluded to in this section were built of wood. Wood can be pressure-treated to withstand the elements, or it can be sealed and painted. It often lasts longer and requires less care than metal. It is easier to work with, and its surface traction makes it safer for children to climb on than metal.

MATH-RELATED ACTIVITIES

1. Graphs or charts of seasonal sun movements relative to the time of day
2. Probability and drainage patterns/problems
3. Problems and activities with regard to geometric forms: balance, symmetry, rigidity, dimensionality
4. Scale, perspective, and function problems
    - How big does a playground unit have to be to accommodate a variety of clients?
    - Will the proposed structure fit the scale of its environment?
    - Will it dominate or get lost?
5. Bids for an architectural project which include estimates of workhours required, materials, profit, and completion date
6. Ratio (cost per person) problems
    - How much will it cost to restore a vandalized park, classroom, schoolyard, or whatever?
    - What would the cost per person be in a community of 10 000?
    - How many hamburgers could be bought for this amount?
7. Ratio problems
    - Mulch to soil (with or without the temperature factor)
    - Length of material which must be sunk into the ground or concrete to support a given structure

MODEL III: MY PLACE IS A SPACE

Like many MARA projects, My Place Is a Space was intended to develop visual literacy, to stress the importance of planning and critical thinking, and to give students practice in many uses of scale. Because the products were very personal, students became directly involved with the concept of personal space as a place. The structures were not permanent. The materials used were 1m x 1.5m sheets of corrugated cardboard, vast quantities of package tape, matte knives, poster paint, and magic markers. The model was developed for a fourth-grade class, but it can be modified for use with other age groups. The element of fantasy within the bounds of function was encouraged. The architect made six visits to the class.

ART LEARNINGS

Elements of Design
- color
- form
- light
- line
- shape
- space
- texture

Orientation

The first and second sessions with the architect were used to introduce the students to the concept of structure and to acquaint them with the architectural processes of making a program for a project. The principles of columns and beams were demonstrated and examples of structure in homes, classrooms, and other places were discussed. The students discovered how structure is used to help define a place. Using examples of places and spaces in the school, they discussed particulars of height, width, depth, texture, light, color, and material. Then they performed such experiments as the following:

- Explore the strength of a single sheet of tablet paper by:
  - Folding it in half and standing it on edge (with the fold running from top to bottom), and then placing one, two, three, or more pencils across the top.
  - Folding each half of the paper in half, setting it on edge to form a closed triangle, and then placing the rest of the tablet on top.
  - Rolling the paper into a cylinder, paperclipping or taping it closed, and experimenting with it as a support for different items.

MATH LEARNINGS

Problem Solving

Geometry
- parallel lines
- intersecting lines
- perpendicular lines

Measurement
- length
- area
- perimeter
- weight
- ratio
- proportion

ART LEARNINGS

- Explore the relative strength of various materials - newsprint, bond paper, cardboard, wood, plastic, and metal.

- Explore the post-and-lintel system, using pencils, straws, or popsicle sticks, with styrofoam, clay, or plasticine as a base.

Analysis

The architect explained to the children that one of the main considerations in designing an environment or structure is the client who requested it. Since the items to be designed and built in this project were personal spaces, the clients were people they should know well - themselves. In addition to dreaming a little, then, the students were asked to think about themselves for a while and consider such questions as the following:

- What kind of person am I? What kinds of things do I like to do most? Do I like to do them alone or with other people - or some of each?

- What kinds of space am I comfortable in? open space? closed space? colorful space? crowded space? quiet space?

- What do I want to do in my space?

- Do I want my space to be like other spaces, or different? stand by itself, or be attached to someone else's?

- Do I like round, squared, or irregular shapes? smooth, rough, or varied surfaces? lots of wall or lots of windows?

- How can I make my space look the way I want it to?

MATH LEARNINGS

ART LEARNINGS

Scale Drawing

Design

The answers to their questions formed their programs and design criteria, and, by the end of the second session, each student had a design of "My Place" ready for critique.

Before the third session, the teacher obtained parent assistants, divided the class into teams of two, and cleared a large space on the classroom floor to use as a work area. Each team agreed on a composite "Place" design which was drawn to scale. Each child made a meter stick. The third session was spent changing two-dimensional drawings into three-dimensional cardboard elevations, making the necessary adaptations and changes as the work progressed. The students became aware of scale, proportion, and dimensionality. (Planning and layout take time, but these steps are absolutely necessary.)

Construction

By the fourth session, the students, with the assistance of teachers and parent aides, were ready to transfer their drawings onto large cardboard sheets. As they measured and drew, the students discussed what their places would look like when they were finished. Once the drawings were transferred and enlarged on the cardboard, the scale, form, and size of each place became much easier to understand.

The fifth session was devoted to taping the cardboard pieces, again with the assistance of two or three parent aides and the teacher. Then the students were led to answer the following questions:

1. Does your place look the way you thought it would?
2. Do you like it? Why or why not?
3. What gives it an identity all its own, and what is that identity?

MATH LEARNINGS

Metric Measure

Ratio

Proportion

Dimensionality

Measurement

Scale

ART LEARNINGS

Perspective

Color
primary
secondary

Form
biomorphic
geometric

Space
open
closed
relationship

Appearance

Fitness/Appropriateness

4. What would happen if it were bigger, longer, taller, or smaller?

5. What does it feel like to be in a space that is round, square, or oblong?

6. What do you see when you look out?

During the sixth session, the flattened units were carried to the gym, set up and retaped, placed on drop cloths, and painted in imaginative fashion with primary colors. The collections of spaces created the sense of a village, and the architect commented that the random placement of the projects was perhaps the most honest means of representing what happens with built forms in reality. To reinforce the concept of city planning, however, the architect drew grids of city streets, country roads, and cul-de-sacs on a large piece of paper and the students used this as a map, locating their places on it. This led to a productive discussion of the different interior and exterior space relationships that developed. Questions about density, security, open space, and other features of the village were discussed. Then the units were placed in the gym according to their location on the map, and more thoughts and reactions were prompted.

Evaluation

The project ended with an open house which gave the whole school an opportunity to visit the places and hear about the project firsthand from the children who had created it.

MATH-RELATED ACTIVITIES

1. Observing existing spaces and the structures which help to define them

2. Measuring not only structures but empty spaces as well

MATH LEARNINGS

Proportion

Geometric Form

Statistics
data gathering
2-dimensional graphing

- How high must a structure be for a given person to stand up in it?
- Where should a window be?

3. Translating little things into big things, using mathematical formulas and proportions
4. Exploring the building properties of geometric shapes (e.g., by pushing or shearing a rectangle into a parallelogram)
5. Identifying the steps involved in problem solving
6. Exploring ways of using materials with minimum waste (e.g., laying out pattern pieces)

RELATED PROJECT

Hamster Habitat

This is a short-term, inexpensive project completed by a third-grade class. It seems especially suitable for young and/or impatient students. The most important feature of the project is "interviewing the client" and determining the full range of its needs and interests before developing a program.

Among the things the third-grade architects needed to know about their small clients were the obvious features of care and feeding, and such additional information as the following:

- Although hamsters average 13 cm in length (including tail) and weigh only 110-140 g, they are active creatures that require a certain amount of space.
- In their natural environment, hamsters make their homes in deep and complex tunnels in the earth.
- Hamsters have strong teeth and are able to gnaw through many substances.
- Wheels will keep them happily running in place for relatively long periods of time.
- Sources of food and water must be readily accessible to the keeper as well as to the hamsters.

The students acquired much of their information through direct observation and discovery, but they also spoke with local pet store and nature center personnel. The answers to their questions and the additional information derived from the "consultants" and from reading helped to determine the program and design criteria for the project.

Once the program and the design criteria had been established, the students expressed their ideas individually in freehand drawings. These were later drawn to scale, modeled, and then critiqued by the other members of the class. In many cases, the students liked some aspects of a given design but found others impractical, unattractive, or inappropriate. The final product combined the best features of several designs. It was a teepee with a wire frame shaped with pliers and covered with hardware cloth. A removable pan was added to the base as an aid to cleaning. The habitat was strong, portable, and relatively small. Since the size of the structure limited the number of students who could work on it at any given time, the students formed "construction gangs" and worked in shifts so that each student could have a hand in the operation.

MATH-RELATED ACTIVITIES

1. Determining an appropriate scale for an animal (guinea pig, turtle, rabbit) habitat
2. Charting the animal's activity patterns and determining the size of the three-dimensional space necessary to accommodate its activity
3. Identifying the geometric forms most adaptable to the animal's needs
4. Estimating a materials budget for the project
5. Determining the amount of ground cover needed for the floor of the habitat
6. Estimating a maintenance budget for the animal
7. Graphing the amount of time used by the client for exercise, eating, and sleeping
8. Graphing the animal's waking and sleeping periods on a clock graph
9. Estimating the probability of use of various exercise structures

MODEL IV: MOON VILLAGE

This was a quick, exciting project which had an especially dramatic effect when it entered its social phase and was ready for outside visitors. It was also very inexpensive because it involved inflatable structures.

ART LEARNINGS

Fantasy

Imagination

Elements of Design
- color
- form
- light
- line
- shape
- space
- texture

Analysis

The architectural problem is implicit in the question, "What would your house look like if you had to pack it up and take it to the moon?" Certain design criteria are immediately apparent. The weight of the structure poses a different kind of problem on the moon than in transit. The move therefore suggests an inflatable structure that can be collapsed, moved, and reinflated. Since travel to the moon is not yet practical for fieldtrips, the students chose the school gym as their building site. The number of moon houses they constructed was determined by the size of the gym and the amount of money available for materials, which consisted of heavy-gauge polyethylene plastic sheets and kilometers of heavy-duty plastic tape. Window fans were used to inflate the structures.

Design

The project was completed in a school that had been discussing life in the year 2001 in English, social studies, and science education classes across all grade levels. The fourth, fifth, sixth, and eleventh grades participated in the design and construction of the plastic village, with each class making a 3m x 6m (or larger) structure and connecting one to another by plastic tubes so that an enclosed tour was possible for anyone who was willing to crawl for a while. Materials for the products cost less than $100. (Safety note: Once inflated, the structures deflate slowly but are light enough to permit anyone trapped by loss of air pressure to punch a way out. In case of fire, the plastic is self-extinguishing.)

The process used for developing the fantastic inflatable structures of Moon Village was exactly the same as that

MATH LEARNINGS

Problem Solving

Proportion

Measurement
- length
- perimeter
- area
- volume

ART LEARNINGS

Scale

used for all of the projects described in this publication: analysis, design, construction, and evaluation. Analysis produced questions like the following, and the answers formed the basis for the design criteria. How big and how strong should the structure be? How many pieces should it have? What kinds of forces must the materials be able to withstand? Are there existing inflatable structures which can be examined? What supports an inflatable structure? How do you provide circulation, light, and heat for living things like people and plants? How safe is the plastic? Can inflatable structures have doors and windows? Will leaks make the houses fall down?

Design

After the design criteria had been developed, individual scale models were made with food bags and scotch tape and inflated by portable hairdryers to test construction concepts. Adjustments were made to the designs and each class created a composite from individual or team-produced designs according to consensus.

MATH LEARNINGS

Problem Solving

Ratio

Proportion

ART LEARNINGS

Volumetric Forms

Positive/Negative Space

Construction

The next steps were to translate the flat plastic shapes into volumetric forms and connect them to each other. When all of the structures had been assembled and connected in the gym, the students had the pleasure of inflating them and traveling through them, which, among other things, provided a kinesthetic understanding of positive and negative space.

Evaluation

When the project was ready for use, the drama was enhanced for outside visitors by the addition of lights and the well-known Richard Strauss opus, "Also Sprach Zarathustra" (the theme from the movie "2001"). As the lights and music played, the fans were turned on and the structures rose in eerie array from the gym floor.

After the final tours, Moon Village was carefully disassembled and each structure returned to the class that had built it for safe-keeping until needed for another fantastic experience.

MATH LEARNINGS

Area

Circumference

Volume

Solids
- **pyramid**
- **sphere**
- **cylinder**
- **cone**

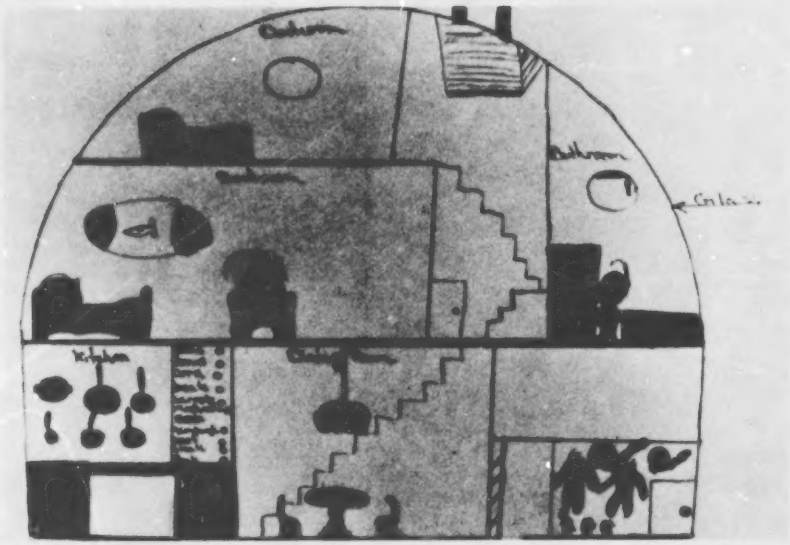
MATH-RELATED ACTIVITIES

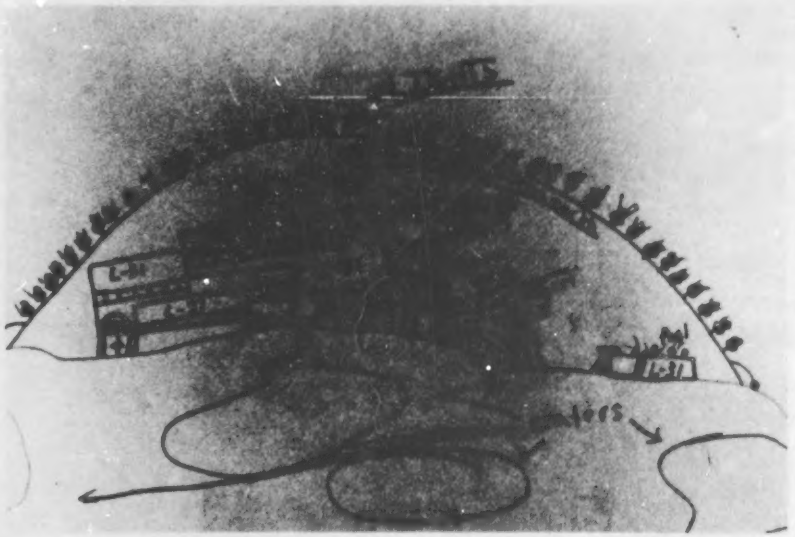
1. Converting two-dimensional shapes into three-dimensional forms (e.g., circles into spheres, squares into cubes)
2. Discovering and measuring geometric shapes used in construction
3. Translating scale models into full-sized structures
4. Determining the most cost-effective way of laying out a pattern on a standard square of plastic
5. Estimating the amount of tape required for taping the seams of a given structure

RELATED PROJECT

Tomorrow's House Today

In this project, a fifth-grade class working with an architect-in-residence undertook the design of pleasing, energy-efficient homes in which the environment was something of a partner. It was a fairly sophisticated task, especially for 10-year-olds, but they completed it well and continually amazed the architect with their creativity.





As a beginning, the children examined existing models and designs, discussed ways of working with the environment, and considered such options as the following:

- Using the box-within-a-box or thermos-bottle concept of overall design.
- Using the earth (which tends to retain a constant temperature of 55°) as a temperature control by sinking the structure into the ground or building it into a hill.
- Installing double glazed windows and air-lock doors.
- Glassing in southern exposures to provide a view and let the sun (heat) come in.
- Building a greenhouse or conservatory, with control louvres, which will act as a thermal mass or storage and also be a place to grow food and flowers.
- Including an indoor pond for food fish.
- Installing fireplaces with parabolic backs which promote more efficient heat distribution.
- Using a silo water tank to store heat from the fireplaces.
- Putting a wind generator on top of the structure and providing 12-volt battery banks to store the extra energy.

This project ended with a critique of each design but could easily have continued through the remaining stages of the architectural process. However, since developments in this field are rapid and materials expensive, the instructional team felt that awareness of the advances and some of the materials, concern for the environment, and orientation toward the future were sufficiently important educational outcomes to terminate the project at this point.

Architecture Spoken Here

A GLOSSARY OF TERMS

RELATING TO THE ENVIRONMENT

biota	the plant and animal life of an area
conservation	the practice of preserving natural resources for the future
density (demographics)	the average number of people or items per unit of space
ecosystem	the living and nonliving factors of an environment considered as a unit
environmental impact	the effect man has on the natural environment
fauna	the animal life of an area
flora	the plant life of an area
groundwater	water within the earth that supplies wells and springs
habitat	the physical place where an animal or plant lives
herbicide	a chemical used to destroy or inhibit plant growth; a selective weed killer
microclimate	the local climate of a small site or habitat
model	an idealized three-dimensional representation on a reduced scale of something existing or yet-to-be-built
open space	unbuilt or undeveloped land
plan	a drawing showing the top view of a design
section	a drawing or representation of something as it would look if cut through (e.g., a section of an apple or a vertical section of a building)

site plan	a scale drawing which shows in detail all dimensions and existing uses for a specific piece of land or space
slope	a natural or artificial incline, as a hillside or terrace
surface water	water which remains on the top of the land
symmetrical	able to be divided into congruent halves (mirror images)
understory	the woody plants growing under the large trees in a forest
watershed	the area which supplies the water to a given stream or water course
wetland	an area that is regularly wet or flooded by water, like a swamp or bog
zoning	the demarcation of a planning area by law, which governs the use of the land

RELATING TO HORTICULTURE

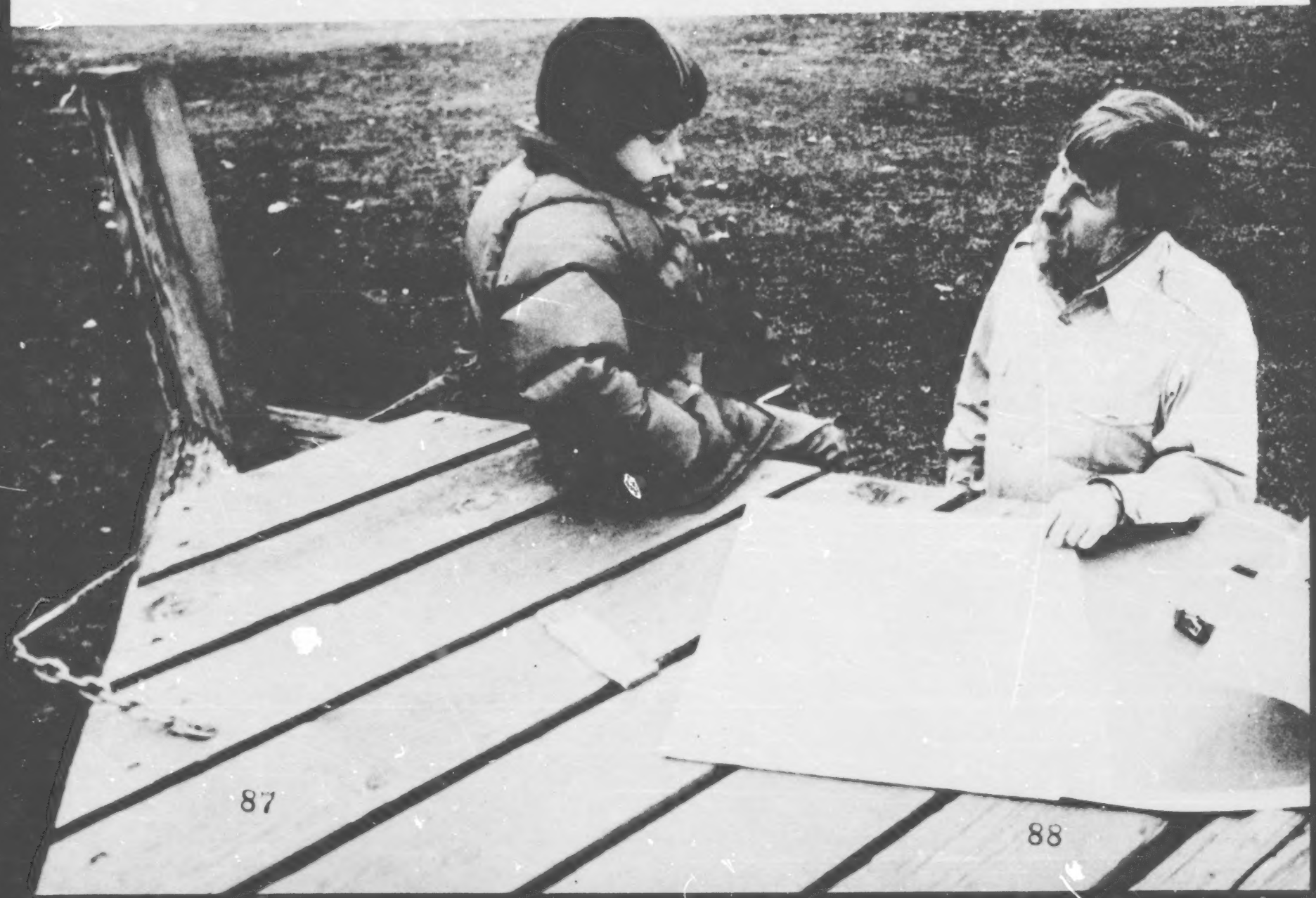
annual	a plant that completes its lifecycle in one year
conifer	a plant that bears its seeds in cones
deciduous	dropping or shedding leaves at the end of a growing season
evergreen	keeping foliage and therefore staying green all year
perennial	a plant that lives for an indefinite number of years
propagation	the act of reproducing plants
vegetation	plant life or plant cover, as in an area, forest, or prairie

RELATING TO LAND PLANNING AND DESIGN

asymmetrical	a lack of congruence between the halves of an object
base map	a drawing showing the fundamental information in a plan

bedrock	the solid rock either on or beneath the surface
buffer	an area used to separate areas of different or conflicting land use
contour	an imaginary line connecting points of the same elevation on the earth's surface
contour map	a map showing the configurations of an area by means of contour lines drawn at regular intervals of elevation
development	a built-up tract of land
elevation	a drawing showing a sideview of a design, as of a building
erosion	the wearing away of the earth's crust (soil) by natural agents such as water or wind
esthetics	the quality of human perceptual experiences
grading plan	a drawing showing how soil is to be rearranged to promote the movement of water across a given area
landscape	the landforms of an area as produced by nature or man
landscape architect	one whose profession is the arrangement of land for human use and enjoyment

An Architect Lends A Helping Hand



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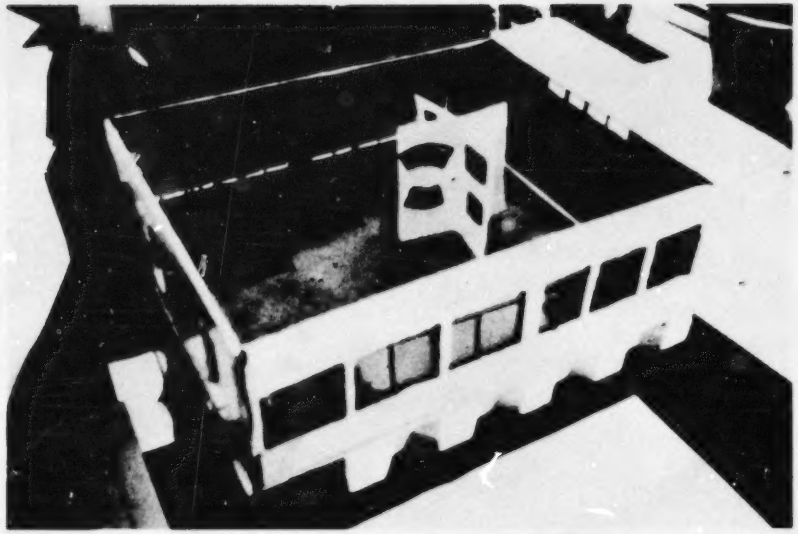

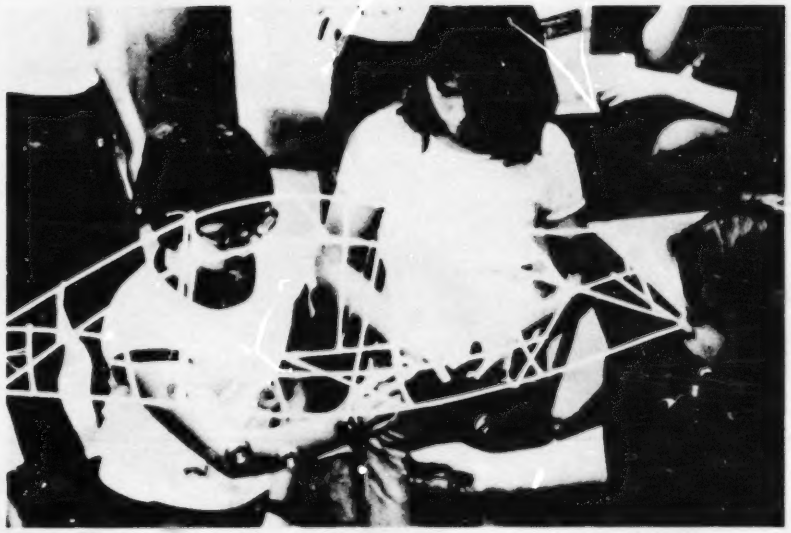

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